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The Influence of Salts on the Radar Detectability of Subsurface Liquid Water in Icy Shells

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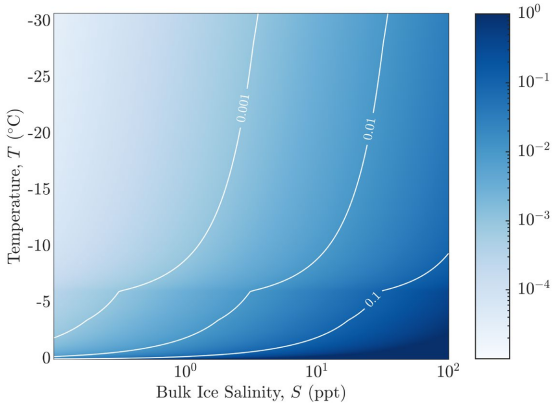

Liquid water is an important target for missions exploring icy ocean worlds to investigate their habitability. NASA's Europa Clipper—launching October 2024—and ESA's JUpiter ICy moons Explorer (JUICE)—launched April 2023—missions will use ice-penetrating radars to probe beneath the surfaces of Jupiter's ice-covered moons Europa, Ganymede, and Callisto in search of liquid water. In this work we study how the composition and concentration of non-ice impurities influence the search for liquid water with ice-penetrating radar. We follow the approach of [1] and use PHREEQC freezing simulations to build models representing the volume fraction of brine as a function of temperature and salinity for a range of different impurity compositions (e.g., Figure 1). We represent the dielectric properties of the ice shell as ice-brine mixtures [2]—highlighting uncertainties that could be mitigated by future laboratory measurements. We demonstrate that although detection of the ice-ocean interface is challenged by the presence of salts, detection of eutectic interfaces (i.e., the minimum depth at which brine becomes thermodynamically stable) can be facilitated. We emphasize how measurements of surface composition can inform the interpretation of future radar data collected at these moons.

Figure 1. Volume fraction of brine in ice as a function of temperature and bulk ice salinity for the Europa K1a ocean of [3], obtained from the output of a PHREEQC freezing simulations for a pressure of 1 atm. The simulation was performed using the ColdChem database augmented by the molar volumes and diffusion coefficients of the frezchem database.

[1] Wolfenbarger et al. (2022), *JGR:Planets* 127(9), e2022JE007305.

[2] Sihvola (1999)

[3] Zolotov and Shock (2001), *JGR:Planets* 106(E12), 32815-32827.